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Minimally Invasive Techniques for the Management of Lumbar Disc Herniation

Anthony T. Yeung, MD[a,b,*], Christopher A. Yeung, MD[a,b]

[a] Arizona Institute for Minimally Invasive Spine Care, 1635 East Myrtle Avenue, Suite 400, Phoenix, AZ 85020, USA

[b] Department of Orthopedics, University of California San Diego School of Medicine, San Diego, CA, USA

Minimally invasive surgery is the current trend for all types of surgery, especially in the spine, where surgical approaches and procedures are still considered by many as a treatment of last resort unless there is evidence of progressive neurologic involvement. In part, the hesitation to consider surgery is due to concerns over the morbidity of traditional spinal surgery, which damages muscle during the approach to the spine. Minimally invasive discectomy is considered desirable by most patients and by many surgeons. For lumbar disc herniation, however, the degree of minimal invasiveness varies widely between surgeons. The most common modern adaptation of a minimally invasive technique is described as a microlumbar discectomy.

Microlumbar discectomy affords several advantages. The use of smaller incisions is made possible by specialized mini-retractors or tubular retractors that dilate muscle. Many use an endoscope or operating microscope. For less invasiveness, the muscle is split along muscle planes or dilated. Smaller incisions have defined most microdiscectomies being performed today. Minimally invasive adaptations of standard laminectomy, discectomy include smaller incisions, smaller retractors, surgical techniques that use minimal manipulation of the nerve root, blunt fenestration of the annulus, and removal of only the sequestrated fragment or fragments that can be extracted readily through the annular defect.

History

Minimally invasive surgical techniques in the lumbar spine were first studied and validated scientifically using chymopapain as an intradiscal injection. Its efficacy and advantages over placebo have been documented by randomized double-blind studies [1,2]; however, its overall efficacy was not as great as traditional discectomy. Endoscopic discectomy by way of the foraminal approach was compared prospectively with laminectomy/discectomy by Kambin [3] and Mayer and Brock [4]. These investigators concluded that when patient criteria for endoscopic discectomy were met, results were equal—but surgical morbidity was lower and patient satisfaction was higher—with the endoscopic technique.

Modern minimal access surgery for lumbar disc herniation was reported independently by Kambin and colleagues [5–9] and Hijikata [10] as early as the mid-1970s. The technique used a posterolateral approach outside the spinal canal and posterior to the abdominal cavity. The original goal was to decompress radiculopathy secondary to lumbar disc herniation. The early efforts were limited to a nonvisualized central discectomy to achieve an indirect decompression of the nerve roots [11,12]. Improvements in the surgical method and equipment evolved gradually over the next 30 years [13–17]. Within the last 5 years, important major equipment advances have included a high-resolution rod lens operating

* Corresponding author.
E-mail address: dryeung@sciatica.com (A.T. Yeung).

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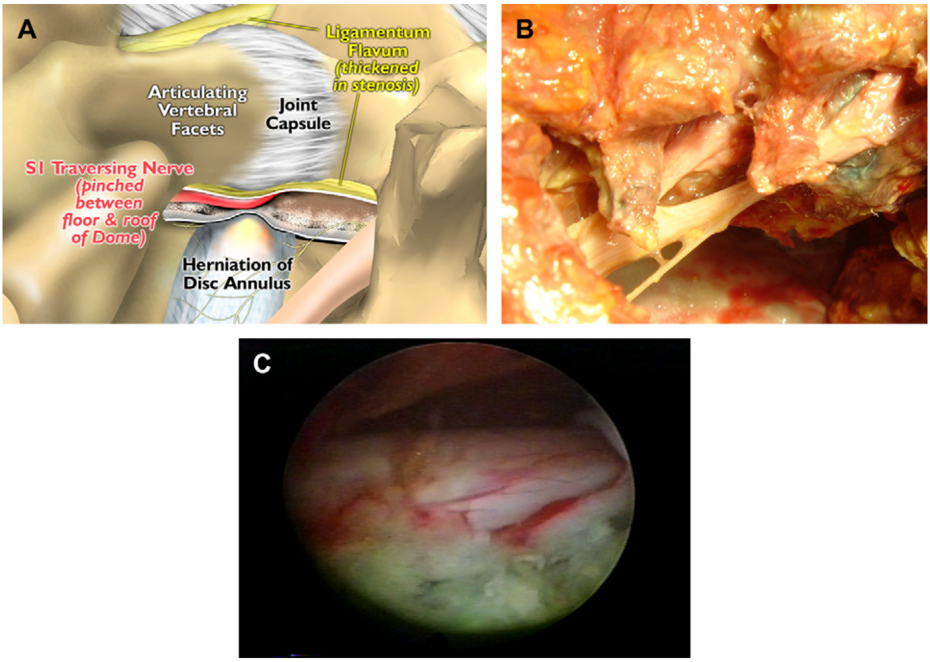

Fig. 1. (*A*) The posterolateral transforaminal portal to address a herniated disc. (*B*) A cadaver dissection illustrating the posterolateral transforaminal portal. The foraminal portal to the disc, described as Kambin's triangle, is bordered by the superior facet of the inferior vertebra dorsally, the exiting nerve cephalad and volarly, and the endplate caudally. Besides normal anatomy, pathoanatomy can be visualized by the endoscope, placed in this triangle for removal of disc herniations. (*C*) Intraoperative image illustrating the decompressed traversing nerve.

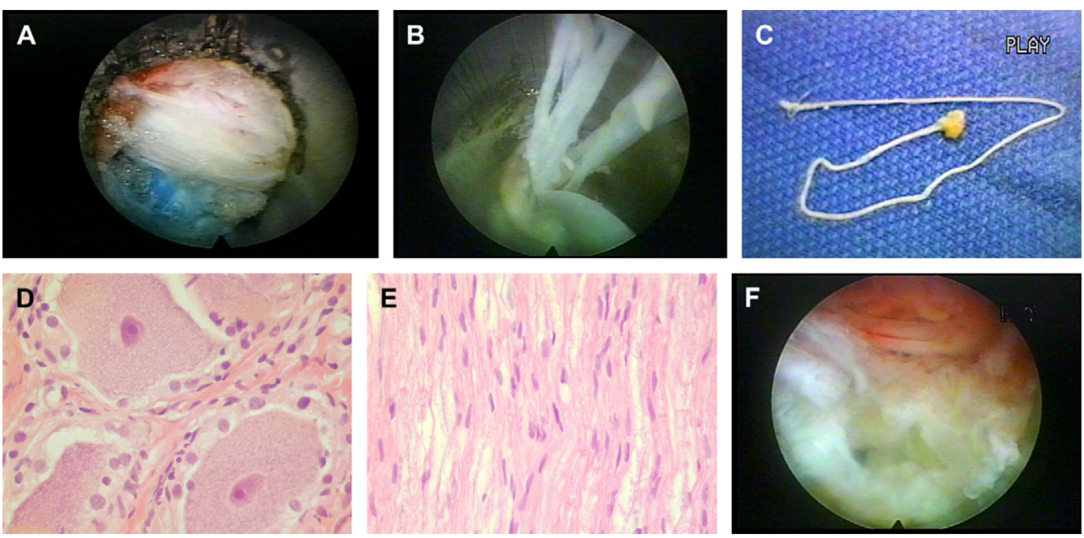

Fig. 2. Anomalous anatomies in the foramen. (*A*) Conjoined traversing nerve visualized in the dorsal foramen under the superior facet lateral to the traversing nerve. (*B*) Anomalous autonomic nerve in area lateral to the traversing nerve. (*C*) Biopsy of autonomic nerve. Histologic images illustrating ganglion of autonomic nerve (*D*) and the peripheral nerve portion of the autonomic nerve (*E*). (*F*) Small furcal nerve in lateral foramen.

endoscope, beveled cannula, bipolar flexible radiofrequency (RF) electrode, and side-firing holmium yttrium-aluminum-garnet (YAG) laser [14–17]. An improved fluoroscopically guided approach, introduced by Yeung and Tsou, outlined a consistent technique for entry into all lumbar posterior disc spaces, including the L5–S1 level [14–17]. These refinements enhanced the capabilities of the endoscopic discectomy to approach the results obtained with traditional transcanal

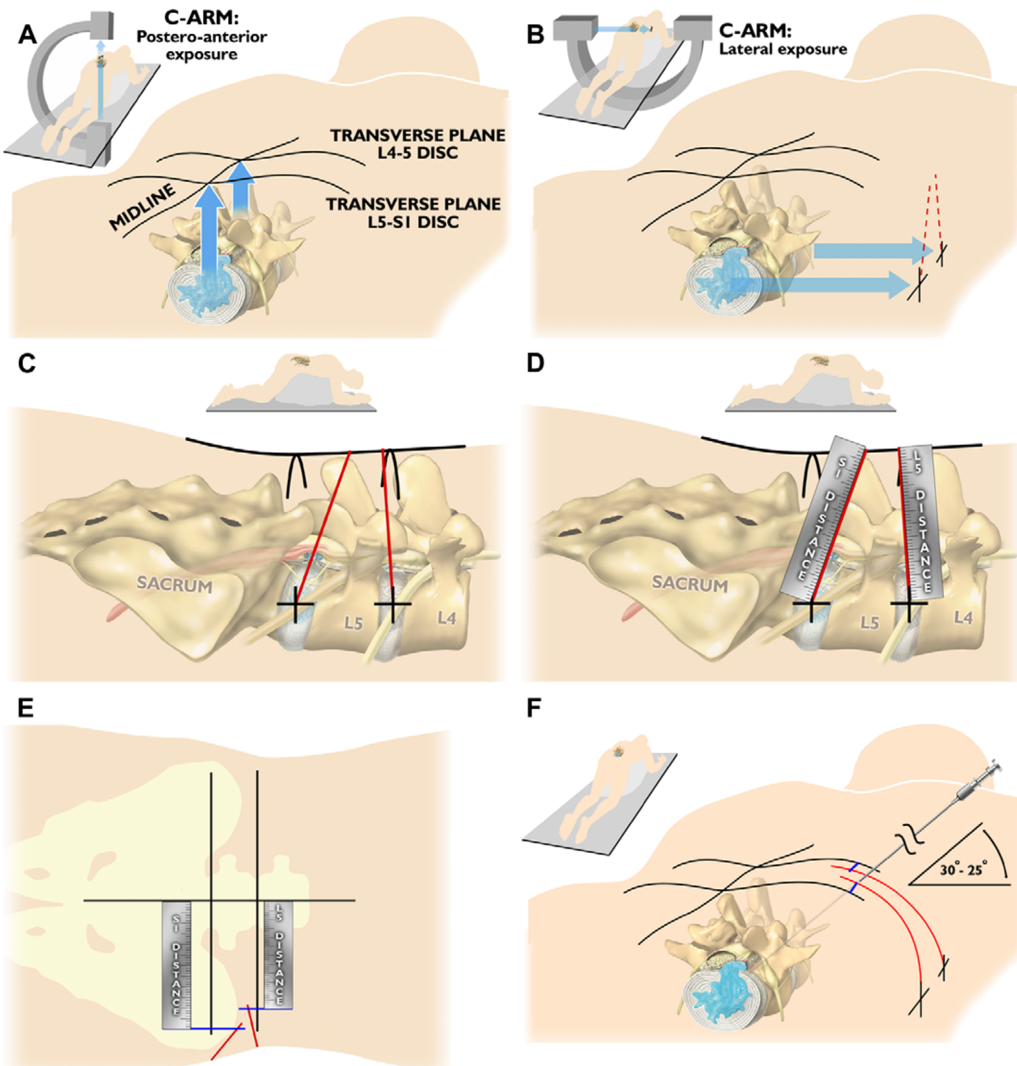

Fig. 3. Protocol to obtain optimal placement of the instrumentation. (*A*) Intraoperative posteroanterior fluoroscopic imaging is obtained to facilitate the topographical location of the midline and transverse planes of the target discs. (*B*) Intraoperative lateral fluoroscopic imaging is obtained to facilitate the topographical location of the lateral disc center, thereby allowing visualization of the plane of inclination for each disc. (*C*) The inclination plane of each target disc is drawn on the skin from the lateral disc center to the posterior skin surface. (*D*) The distance between the lateral disc center and the posterior skin surface plane is measured along each disc inclination line. (*E*) The distance is measured from the midline along the respective transverse plane line for each disc. At the end of this measure, a line parallel to the midline (blue) is drawn to intersect each disc inclination line (red). This intersection marks the skin entry point or "skin window" for each target disc. (*F*) A needle is inserted at the entry point toward the target disc at a 20° to 25° angle to the surface skin plane. This trajectory determines the path of all subsequent instrumentation. (*From* Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003;11:255–63; with permission.)

methods for treating common lumbar disc herniations. The use of minimally invasive technologies, such as chymopapain and laser [18–20], to augment disc decompression has improved endoscopic disc and foraminal surgery.

The learning curve

Only a small number of surgeons who are dedicated to endoscopic discectomy routinely use posterolateral extraspinal canal lumbar endoscopic surgery as their first surgical option. A few academic institutions tried the endoscopic system as an investigational tool, but disc herniations are usually treated by community surgeons and are not referred to academic training centers. The learning curve for spinal endoscopy is steeper than for traditional microscopically assisted open procedures [21]. The first learning barrier is the percutaneous approach itself. The percutaneous approach is facilitated by calculating the exact skin entry point to provide a precise trajectory to target the disc herniation. The second barrier is the lack of a large operating working space once the surgical tools are on target. The third barrier is the need to use multiple operating tools, using both hands and one foot simultaneously. It is the intent of this article to describe transforaminal endoscopic discectomy of the lumbar spine and present new clinical concepts that allow direct visualization of the foraminal pathoanatomy and disc herniations by way of the foraminal portal.

Transforaminal endoscopic discectomy

The technique and equipment for performing posterolateral percutaneous endoscopic lumbar discectomy evolved mostly in the private sector, but they have undergone a slow evolution over the past 30 years. The early percutaneous techniques of automated percutaneous lumbar discectomy, laser disc decompression, and coblation are still image-guided decompressions and not used for the full spectrum of disc herniations. The current procedure began with an arthroscopic microdiscectomy technique introduced by Kambin; however, the current level of proficiency was reached in 2000–2001 after the introduction of a multichannel endoscope with a working operative channel [15–17,22]. Since then, the technique and its indications have continued to improve, expanding to include other degenerative painful conditions of the lumbar spine. As a result of

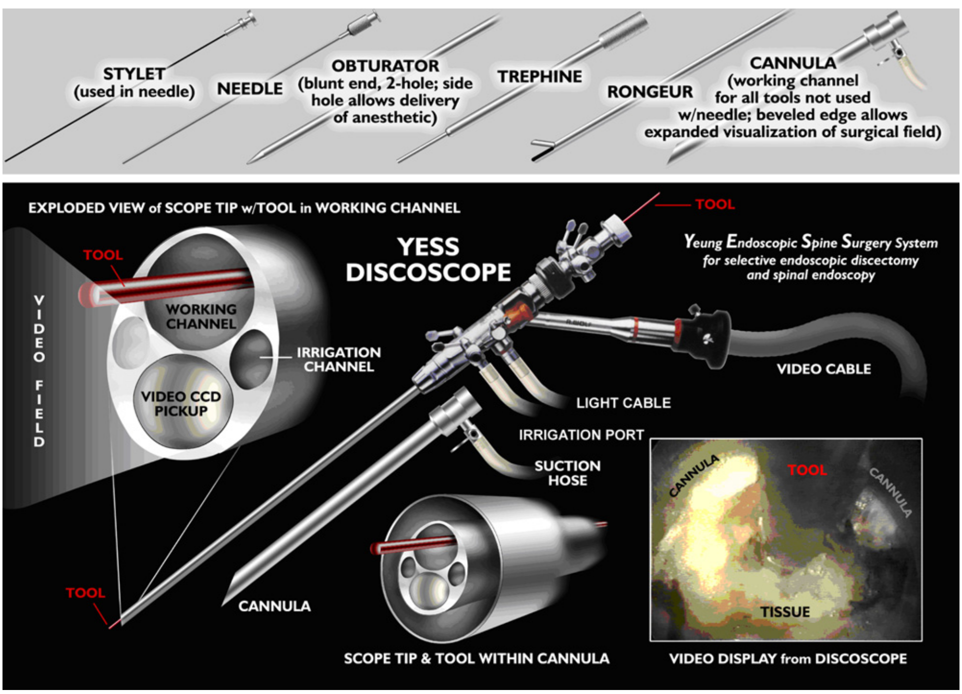

Fig. 4. Instrumentation set for selective endoscopic discectomy. (*From* Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003;11:255–63; with permission.)

combining adjunctive minimally invasive technologies, endoscopic capabilities in experienced hands now closely overlap the clinical efficacies of conventional transcanal open discectomies, but with less surgical morbidity.

The transforaminal endoscopic portal to the spinal segment provides the unique ability to visualize normal variations in foraminal anatomy and intradiscal pathology in MacNab's ''hidden zone'' that is not appreciated by surgeons using a standard posterior microdiscectomy approach (Fig. 1) [22]. The visualization of conjoined nerves, furcal nerve branches, and anomalous anatomy (eg, sympathetic nerves) may help to explain why some patients with identical imaging studies have debilitating pain whereas others do not. These variations in the normal anatomy and anomalous nerves in the foramen also present a new set of surgical risks to the endoscopic surgeon (Fig. 2). Intradiscal visualization is enhanced by incorporation of intraoperative discography and staining of the disc with 10% indigocarmine dye. This blue dye selectively stains degenerated nucleus and annulus, providing color contrast to help differentiate degenerative tissue from normal tissue.

Biplane intraoperative fluoroscopic images are used for percutaneous guidance. The approach trajectory starts from an optimally located skin window, entering the disc through the foraminal annular window. This starting point is calculated by drawing the trajectory on the skin by a protocol previously described as part of the Yeung endoscopic spine system technique for needle placement (Fig. 3) [14–17]. The exiting nerve is retracted from harm's way with a dilator, first by inserting a needle into the disc without causing leg pain followed by a beveled cannula as a tubular retractor and a surgical access tunnel. If an inside-out technique is used, a cavity in the disc must be created for viewing and manipulating the endoscopic tools intradiscally. Some endoscopic

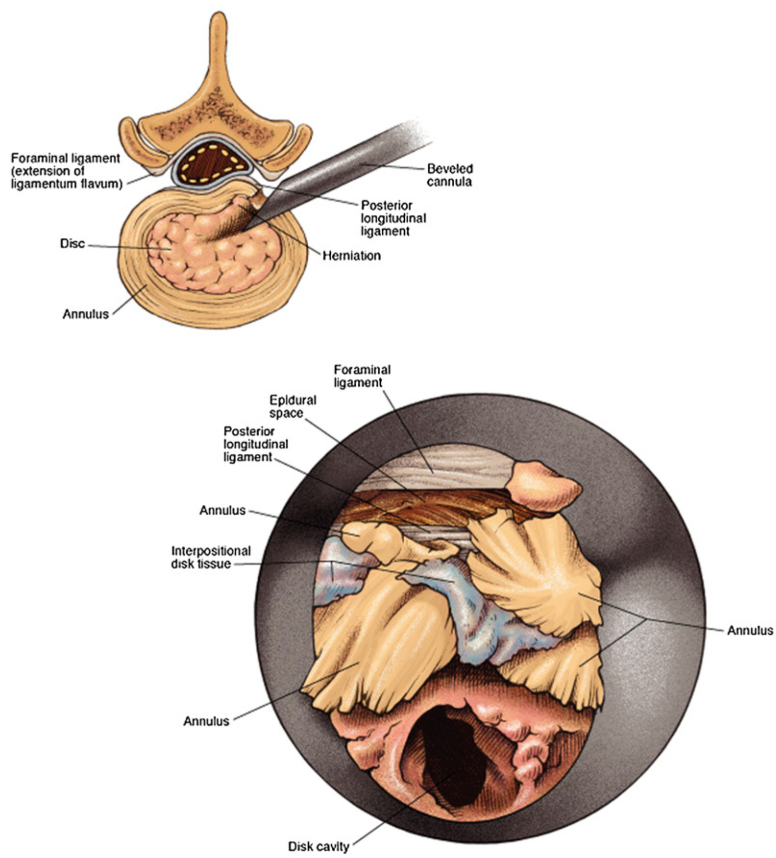

Fig. 5. The transforaminal endoscopic approach to the lumbar spine for discectomy. (*From* Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003;11:255–63; with permission.)

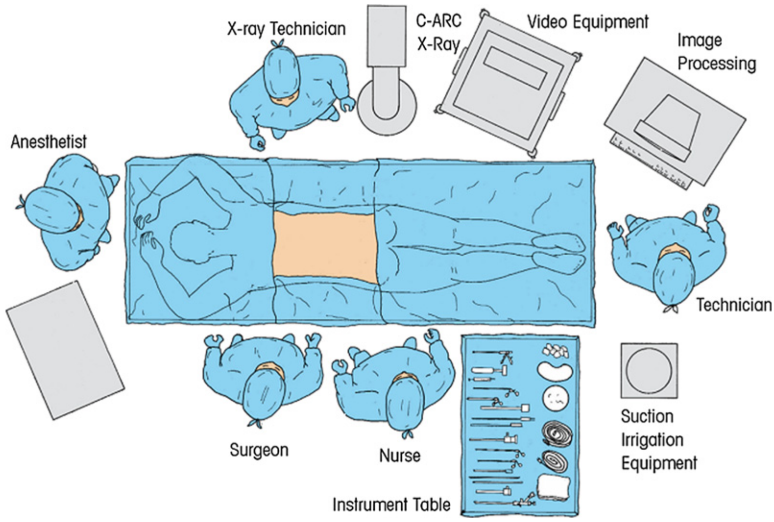

Fig. 6. Operative room set-up.

surgeons target the extruded herniated fragment directly by placing a guide wire to the disc fragment, then by dilating cannulas and cutting instruments into the epidural space to address the herniation. Currently available equipment include a high-resolution rod lens operating endoscope, beveled cannula, trephine, bipolar RF electrode, and straight and side-firing holmium-YAG laser (Fig. 4). Each tool has a unique role in performing surgical tasks.

The learning curve may be steep, but once mastered, the surgeon is able to extract contained and noncontained disc herniations from within the disc or directly from the epidural space (Fig. 5). Granulation tissue in annular defects (tears) can be ablated using an RF electrode. Holmium-YAG laser has the unique ability to divide thick collagenous tissue and ablate cortical bone.

Approach

This procedure is performed in an operating room, using local anesthesia and conscious sedation attended by an anesthesiologist (Fig. 6). The conscious patient is instructed to report any unusual painful sensations to the operating surgeon while the procedure is in progress. The approach begins by placing a needle free hand, under biplanar fluoroscopic guidance, to the posterolateral corner of the disc. When the needle tip is close to the lateral facet or annular window, the conscious patient serves as a dependable alarm system to ensure that nerve irritation is not caused by the needle. In the authors' experienced hands, neuromonitoring has not improved results or decreased surgical morbidity [23]. The usual symptomatic disc pathology is located near the annulus and the posterior one third of the disc space. Therefore, the operating tools are inserted from the skin window at a trajectory of 20° to 25° (see Fig. 3) in the frontal plane toward the foraminal annular window (Fig. 7). The safe lateral boundary of the skin window (needle entry point on skin) can be initiated as an extreme lateral approach that stops before the needle entry point becomes a lateral approach. The needle is docked on

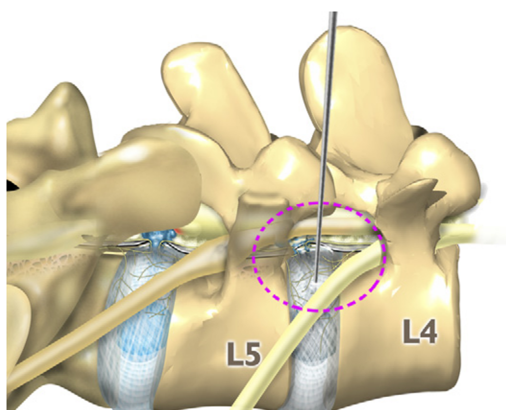

Fig. 7. The "hidden zone" for lumbar discectomy by way of a transforaminal endoscopic approach to the lumbar spine. (*From* Yeung AT, Yeung CA. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003;11:255–63; with permission.)

the annulus as close to the medial pedicular line as possible but not medial to that line. An ideal needle trajectory to the annulus is about 20° from the horizontal plane—and never reaching 0° or the abdominal cavity will be at risk. If an extreme lateral approach is considered, getting a CT of the abdomen with the patient in the prone position is suggested. All subsequent operating tools enter the disc through the same portal. The needle entry point is calculated from the posteroanterior (PA) and true lateral views of the lumbar spine (see Fig. 3A, B). From the PA and lateral views, the skin window location is plotted. The combination of the skin window and the foraminal annular window determines the needle trajectory. Most surgeons are comfortable with foraminal access to the lumbar spine from L4 to L1. Some are wary of the L5–S1 level because of the overlying iliac crest.

At the L5–S1 level, however, the disc space usually is in a lordotic inclination, and direct access to the disc space parallel to the endplates is possible. Once experience is gained with the procedure, if the iliac crest is too high or the space from the lateral facet to the iliac crest is too narrow, specialized trephines and high-speed burrs can be used to remove a small portion of the lateral facet to gain access to the disc.

Case examples of the surgical management of foraminal and extraforaminal lumbar disc

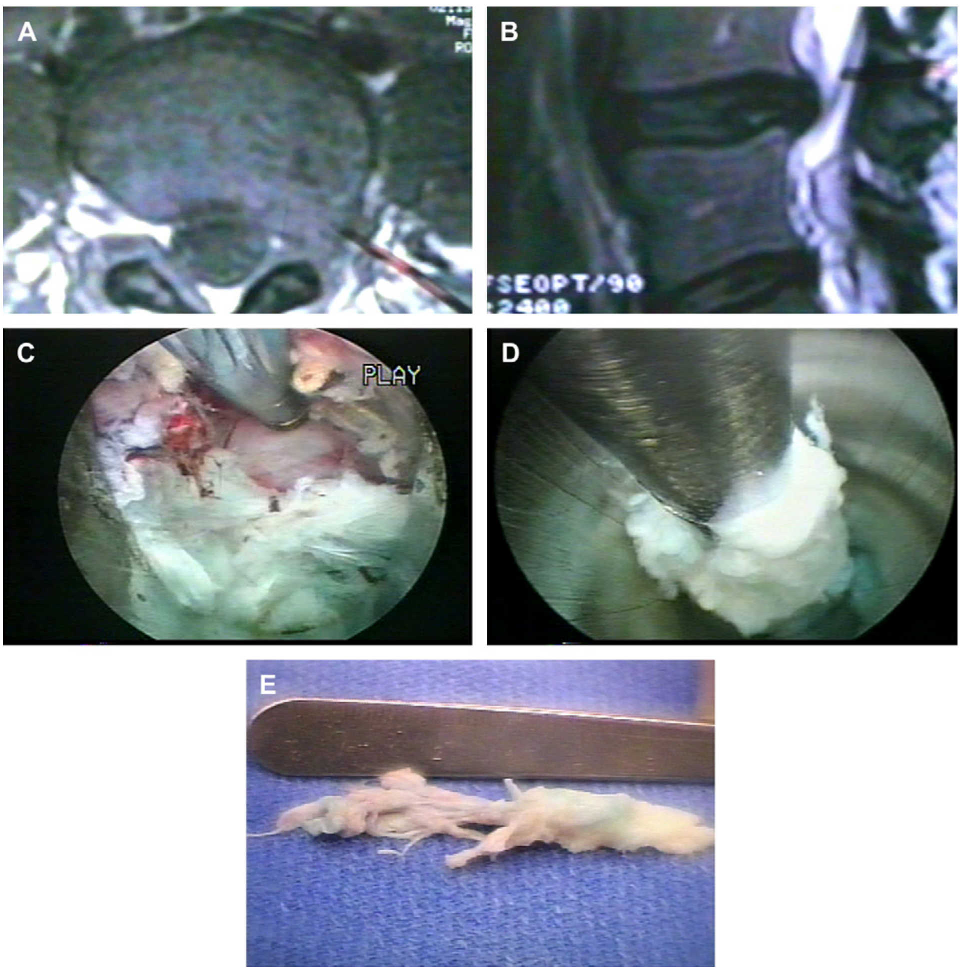

Fig. 8. Case example of surgical management of a foraminal lumbar disc herniation by way of the transforaminal endoscopic discectomy approach. Preoperative axial (*A*) and sagittal (*B*) MRIs of a left-sided L4–5 foraminal disc herniation. (*C*) Direct extraction of the herniated nucleus pulposus using a 6-mm cannula. (*D*) Foraminal view of the decompressed traversing nerve. (*E*) Herniated disc fragment.

herniations by way of the transforaminal endoscopic discectomy approach are shown in Figs. 8 and 9, respectively.

Discography

The subjective provocative response is valuable for confirming the disc as the source of the pain. Evocative chromo-discography [14–17] is a key clinical confirmatory test that links the suspected painful disc to the patient's subjective pain complaints. Blue coloring of degenerated nucleus pulposus and annular defects, using the vital dye indigocarmine in 10% concentration [14–17], identifies pathologic portions of the disc in contained or uncontained herniations. Contiguous disc fragments in the epidural space, disc tissue embedded in annular defects, and herniation tracts also are stained. Nonionic Isovue 300 (Bracco Diagnostics, Princeton, NJ) contrast

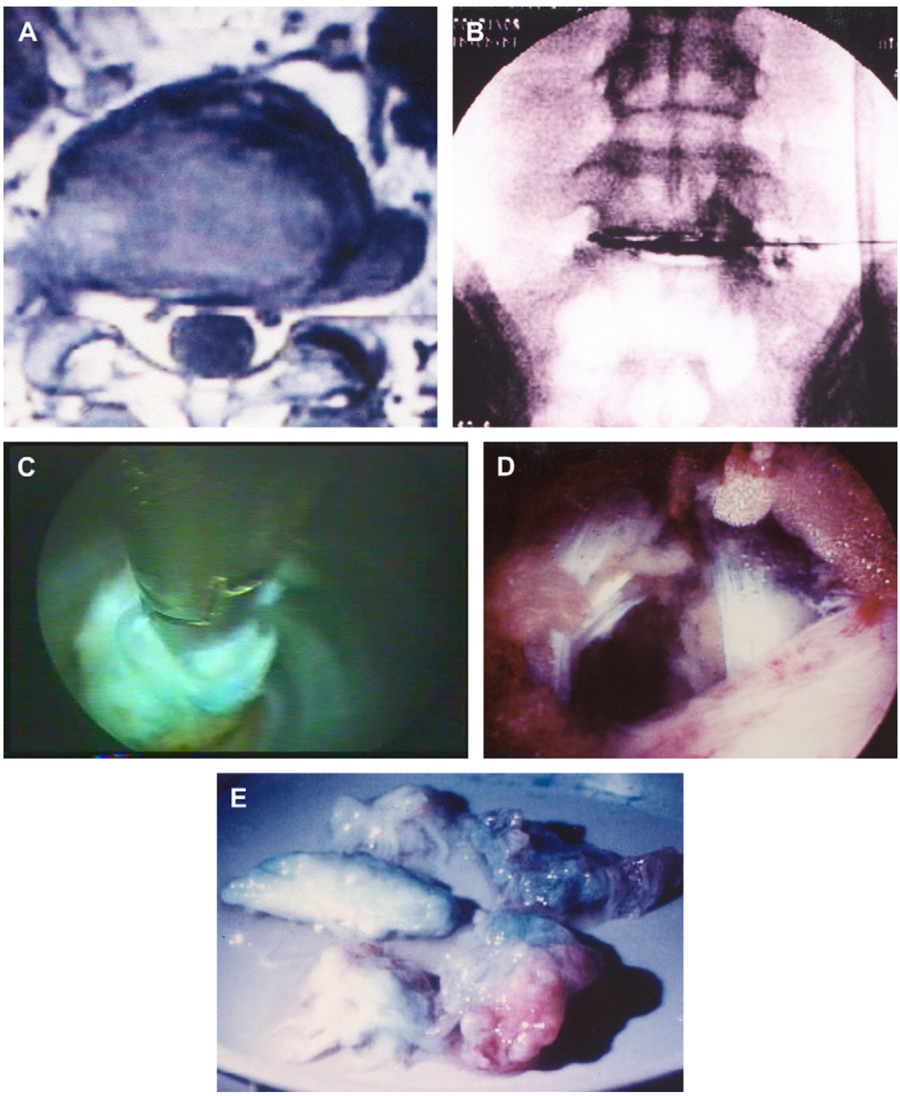

Fig. 9. Case example of surgical management of an extraforaminal lumbar disc herniation by way of the transforaminal endoscopic discectomy approach. (*A*) Preoperative axial MRI illustrating a left-sided L5–S1 extraforaminal disc herniation. *B*) Chromo-discography (Isovue 300 and indigocarmine) helps to identify pathologic disc portions. (*C*) Extraction of the herniated disc material. (*D*) The disc cavity and decompression of the nerve root. (*E*) Extracted disc material.

is mixed with indigocarmine in a 10:1 ratio (see Fig. 9B). In a nondegenerated disc, the roentgenographic contrast permeates the nucleus pulposus and forms a compact oval or bilobular nucleogram [24]. There is no dye penetration into the normal impermeable annular collagen layers. Therefore, the absence of an annulogram represents a normal annulus. In degenerated conditions, clefts, crevices, tears, and migrated fragments of nucleus will be filled with contrast inside the disc and along the herniation tract.

A syringe is attached to the needle by way of an extension tube, and the surgeon correlates the patient's response to the injection of the injectate. Manual pressure graded light, moderate, and high is accurate enough to correlate the patient's response to the injection, thereby correlating the pain generated by the discography process with the volume and pressure of the manual injection. This also must be correlated with the discogram pattern, as described in the literature as normal or abnormal. The literature promotes the use of a transducer to record the intradiscal pressures during the discogram process [25,26]. If the surgeon does one's own discography, however, one rapidly learns to correlate the discographic findings with the endoscopic pathoanatomy and becomes more proficient at patient selection. For patients with ambiguous clinical complaints, a preoperative discography may be desired to better understand the nature of the spinal problem before any surgical procedure; however, intraoperative discography has the advantage of outlining the disc herniation as identified on the preoperative MRI and assists the surgeon in disc removal.

Summary

Posterolateral lumbar discectomy is a visualized method for minimal access to the disc and epidural space that avoids surgical morbidity to the dorsal muscle column. This endoscopic approach also allows for the visualization of foraminal and intradiscal pathology that is not appreciated by the traditional approach. The correlation of these findings with pain generation may open the door to a better understanding of the degenerative process causing lumbar disc herniations; our concept of surgical intervention that encourages patient selection for earlier intervention may evolve as well.

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